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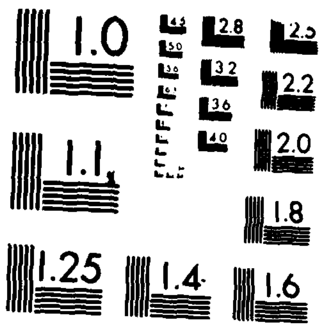

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Investigating the Implementation of Robotics

Linda Argote and Paul S. Goodman

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The Robotics Institute
Carnegie-Mellon University
Pittsburgh, Pennsylvania 15213

February 1984

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Research investigates how introducing robots affects individuals and organizations. Data are presented from two field studies at different organizations introducing robots. The studies focus on three questions. First, how do robots affect individual employees including their job activites, motivations, and stress levels? Second, how do robots affect organizational structures and outcomes? Third, how does the implementation process, including methods of communication and participation, affect employees' reactions and the speed of implementation? Data are collected at each organization at several points in time through interviews with a

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Table of Contents

Abstract

Research investigates how introducing robots affects individuals and organizations. Data are presented from two field studies at different organizations introducing robots. The studies focus on three questions. First, how do robots affect individual employees including their job activities, motivations, and stress levels? Second, how do robots affect organizational structures and outcomes? Third, how does the implementation process, including methods of communication and participation, affect employees' reactions and the speed of implementation? Data are collected at each organization at several points in time through interviews with a variety of respondents, observations, and records data. Strategies are suggested for both researchers studying the implementation of robots and practitioners introducing robots in their organizations.

Our research focuses on how introducing robots affects both individuals and the structure, functioning, and effectiveness of organizations. Robots are being used in increasing numbers in offices and factories throughout the world. While only a few hundred robots were used in the United States in 1970, this number had increased to about 4,700 by 1981 and to about 7,000 by 1983 (Ayres & Miller 1983; Hunt & Hunt 1983). Forecasts of how many robots will be in use in 1990 range between 75,000 and 150,000 in this country alone (Hunt & Hunt 1983). Little is known, however, about how individual workers react to the introduction of robots or about how robots affect organizational structures, processes, and outcomes. The research described here focuses on increasing our understanding about the effects of robots on individuals and organizations.

Following a brief overview of past research on the introduction of other forms of technology, we will (1) discuss robotic technology and its relationship to other forms of technology, (2) develop specific research questions on the effects of robots on individuals and organizations, (3) illustrate the research questions with findings from field studies on the introduction of robots, and (4) conclude with suggestions for both researchers studying the implementation of robots and practitioners introducing robots in their organizations.

While our research program appears to be one of the first on the effects of introducing robots on individuals and organizations, research has been done on the introduction of other forms of technology, such as electronic office equipment (Zuboff 1982; Bikson & Gutek 1983), computers (Mumford & Banks 1967), and other forms of factory automation, including numerical control machines and flexible manufacturing systems (Mann & Hoffman 1960; Whyte 1961; Williams & Williams 1964; Ettlie & Rubenstein 1980; Blumberg & Alber 1982). Certain aspects of the social impact of robotics have also been researched such as how robots affect employment levels (Ayres & Miller 1983; Hunt & Hunt 1983) and how tasks should be divided between robots and humans (Parsons & Kearsley 1982).

Our review of this research identified four general issues relevant for our study of robotics. First, research shows that compatibility between an organization's technical system and its social system affects system performance (Trist & Bamforth 1951; Emery & Trist 1973). Secondly, changes in technology often affect the jobs of individual workers. For example, technological changes have been found to increase the extent to which jobs were mentally demanding (Whyte 1961), and to lead to workers' feeling more responsibility (Mann & Hoffman 1960), less control (Blauner 1964), and a greater sense of stress (Mann & Hoffman 1960; Whyte 1961; Blumberg & Alber 1982). Thirdly, technological change often affects organizational structures, including interaction patterns at work. For example, Whyte (1961) reported that increased automation decreased the opportunities workers had to interact with their coworkers while Williams and Williams (1964) found that numerical control machines required more coordination activities between support and production personnel. Finally, previous research indicates that the very process of implementing change, including the extent of worker participation, can affect workers' acceptance of and commitment to the change (Coch & French 1948; Griener 1967; Tournatzky, Eveland, Boyland, Hetzner, Johnson, Roitman & Schneider 1983).

1. Robotic Technology

The Robot Institute of America defines a robot as a programmable, multifunctional manipulator designed to move objects through variable programmed motions to perform a variety of tasks (Robot Institute of America 1982). Thus, two characteristics, multiple task capability and programmability, differentiate robots from most other forms of automation. The robots used most frequently in U.S. factories today, in jobs that involve moving material, welding, drilling or spray painting, are called level I or first-generation robots. Researchers are developing robots, known as level II or second-generation robots, with more sophisticated

sensing and thinking capabilities. For example, a level II robot that is capable of identifying the location of parts of different shapes and sizes is currently being developed.

We think it makes sense, intellectually, to view robots as another form of automation. Workers may view robots, however, as qualitatively different from other forms of automation. Two factors probably contribute to this perception. First, workers have been exposed to robots with glorified capabilities in the media. Indeed, in one organization we studied, workers felt that they learned the most about robots from television and films, especially the movie *Star Wars*. Secondly, there are more similarities between humans and robots than between humans and other forms of factory automation (Kumpe, Bolwijn, Boorsma & v. Breukelen 1982). Unlike most other forms of factory automation, robots and humans are both capable of moving, responding to changes in the environment, and performing multiple tasks. We think the glorified media image of robots and the relative similarity to humans cause workers to be more concerned about the introduction of a robot than about the introduction of other forms of technology. The research we have completed thus far does not enable us to test directly whether workers do, in fact, perceive robots as qualitatively different from other forms of automation, but there are some indications that this is so. Workers at our first study site named the robot and talked about it as though it had human qualities. Workers did not anthropomorphize other forms of technology at the plant.

2. Research Questions

Based on our review of past research and on discussions with scholars and practitioners about key issues surrounding the introduction of robots, we defined the following research questions:

1. How do individual workers react to and how are they affected by the introduction of robots, including changes in worker beliefs, motivations, and stress levels?

2. How do the structures of organizations, such as relationships between and within departments and decision-making responsibilities, change when robots are introduced?

3. How does the implementation process, including methods of communication and the type and extent of participation affect workers' reactions and the smoothness of the introduction?

4. How do robots, and employees' reactions to them affect organizational outcomes, such as productivity, turnover, absenteeism, accidents, and the flexibility of the manufacturing process?

The results of a recently completed field study on the implementation of robotics provide information about Questions 1, 2, and 3. A second field study, currently underway, provides additional insights into Question 3. Results of these studies will be discussed with special emphasis on Question 3, the question that focuses on the implementation process. Further research is underway to increase our understanding of these questions.

3. The Field Studies

3.1. Design

The first field study used a before and after design, with a control group. Production workers in a factory department where a robot was introduced were interviewed three months before, Time 1, and three months after, Time 2, the robot introduction. Individuals from other departments and levels at the plant, including first- and second-line supervisors and managers, and representatives from engineering, maintenance, quality control, production scheduling, and personnel relations, were also interviewed. In addition, we observed the workplace during the introduction of the robot and administered a satisfaction questionnaire to production workers. The methodology and results of this study are reported in detail in Argote, Goodman, and Schkade (1983). The design of the second field study is similar to the first. The major differences in design between the two studies are the collection of additional data including multiple after measures and archival data on absenteeism, turnover, and productivity at the second study site.

3.2. Sites

The primary technological processes at the first study site involve forging and machining metal products. The work force at the plant numbered about 1,000, was nonunion and predominantly blue collar. The plant, part of a larger corporation, was technologically sophisticated and had previously expressed interest to the parent corporation in using robots. The robot we studied, the plant's first robot, was given to the plant by the parent corporation. The plant's decision about where to place the robot was based on both technical (e.g., what the robot could do, where the plant would benefit from greater consistency) and social (e.g., which jobs involved especially heavy work) concerns.

The robot was placed in a department in which the basic operations were milling and grinding bar stock. There were approximately ten different operations, and forty people worked across three shifts in the department. The robot, operated by one person on each shift, loaded and unloaded two milling machines. No one lost his or her job as a result of the robot's use.

The site of our second field study differs from the first site on key characteristics. The second organization is unionized and already has robots on line. The new installation involves two robots, and displaces some employees, and changes the jobs of employees who are retained. One of the robots in the new installation moves material; the other drills and inserts clips into products.

3.3. Major Findings

Our findings are organized here in terms of our research questions. First, we discuss how the robot affected individual workers. Second, we discuss structural changes, including changes in interaction patterns, associated with the introduction of the robot. Third, we discuss the process of implementing the robot and the effectiveness of communication sources used by the plants to introduce the robots. With the exception of the data on the effectiveness of communication sources, the results reported here are based on data from our first site. Data from both sites are reported about the effectiveness of communication sources.

3.3.1. Individual Employees.

Operators' jobs changed with the introduction of the robot. The robot loaded and unloaded two milling machines. The human operator was responsible for monitoring the robot and provided set-up activities for the two milling machines. The operators commented:

> "The job now requires more skills . . . You have to learn how to program the robot and run it . . . With more skills, of course, comes more responsibility."
>
> "Now it's mainly watching . . . walking around the machines to be sure everything is running."
>
> "We do more activities. Now you have to set up all three machines."

Thus, introducing the robot increased the number of job activities of the robot operators, required more monitoring than doing activities, required more skills, and implied more responsibility. Since jobs with certain characteristics such as variety, significance, control, and feedback are more satisfying and motivating than jobs without these characteristics (Blauner 1964; Hackman & Lawler 1971; Hackman & Oldham 1975), we would expect a technological change that affects these job characteristics to lead to changes in the satisfaction, motivation, and well-being of employees.

How did these changes actually affect the robot operators? The operators reported that they experienced more stress:

> It's nerve racking . . . there are lots of details . . . it's an expensive piece of equipment.
>
> There is more stress now . . . we have more responsibility.

In work in progress, we are identifying the specific elements of the robot's introduction that caused the operators to feel more stress. Based on comments made by the operators and our review of past research on stress, we have identified several potential sources of stress, including: the newness of the technological change, the costliness of the equipment, the severity or increased visibility of the consequences of an operator mistake, the increased mental demands of the job, the possible incompatibilities between the demands of the job and the skills and preferences of employees, and the changes in interaction patterns such as increased isolation from coworkers, or employees' perceptions of a loss of control.

We are attempting to identify which of these factors contribute to the experience of stress we observed for the robot operators. In our second study, we are collecting data over a longer time period to enable us to see whether the sense of stress that we observe at three months after the robot's introduction persists one or two years later. If we find evidence of stress at the three-month but not at the one-year mark, this suggests, other things equal, that the stress was a fleeting phenomenon largely attributable to the newness of the change and that employees have adapted to the new situation. If we observe stress at both the three-month and the one-year mark, this makes it more likely that the stress is due to something inherent in the nature of the change, not to the mere fact that there was a change. By studying multiple robot installations we will also be able to identify conditions under which operators experience stress. For example, examining stress both in situations where introducing a robot decreased employees' opportunities to interact and in situations where the robot did not change interaction patterns should enable us to get a better handle on whether changes in interaction patterns contribute to workers' experience of stress.

We are also examining the effect of this increased stress on individual and organizational outcomes. Studies have shown that increased stress is associated with increased turnover and absenteeism (Porter & Steers 1973), with increased blood pressure and heart rate and higher incidence of heart disease (French & Caplan 1972; Haynes, Levine, Scotch, Feinleib & Kannel 1978; Caplan, Cobb, French, Harrison & Pinneau 1980), and with both increments and decrements in performance (McGrath 1976).

3.3.2. Organizational Structures.

Introducing the robot in our study did not change the basic work flow in the department. The robot operators, however, reported at Time 2 that they had less opportunity to talk with their coworkers than they had had before the robot was introduced:

> I haven't been able to talk as much . . . I'm too involved with the robot . . . You really have to concentrate . . . I don't have time to talk with anyone . . . I'm isolated now.

The major change in interactions, which occurred between support personnel from engineering and maintenance departments and the robot operators, was more frequent contact between the robot operators and these technical support personnel.

3.3.3. Implementation Process.

Our first study site used a broad range of strategies to introduce the robot into the plant, including demonstration, talks by the plant manager, and discussions with first-line supervisors. We asked o respondents at Time 1 whether they learned about the robot from a particular source at the plant, and we als asked them to rate, on a five-point scale, the extent to which the communication increased their understanding of the robot. These data, presented in Table 1, indicate that the most frequently mentioned source of information about the robot was the weekly workplace meeting between supervisors and workers. However, according to workers, these meetings increased their understanding only to a small extent. Written communication and the demonstration at the open house were rated as the most effective sources of information about the robot; however, fewer than half of our respondents attended the open house and only a few reported that they received a written communication. Thus, employees did not perceive the various communication strategies as very helpful in increasing their understanding of the robot.

Further corroboration for these results is provided by the data presented in Table 2. Table 2 presents results from analyses of the effects of whether or not respondents received a particular communication source on their beliefs about the effects of the robot. At Time 1, respondents were asked whether they thought the robot would increase, decrease, or have no effect on various outcomes, and at Time 2 they were asked whether they thought the robot had actually increased, decreased, or had no effect on each outcome. Table 2 presents the results of probit analyses in which the dependent variable was the respondents' perceptions of the effects of the robot on various outcomes, and the independent variables were time and whether or not the respondent received various communication sources. Table 2 shows only the coefficients of the second variable, communication source. A positive coefficient indicates that respondents receiving communication from this source were more likely to believe the robot would increase the outcome; a negative coefficient indicates that those receiving communication from this source were more likely to believe the robot would decrease the outcome.

In general, the results of the probit analyses show that the various communication sources did not have much effect on employees' beliefs about the robot. Of the 32 coefficients shown in the table, only five are significant beyond the .10 level, only slightly more than one would expect through chance. In the five

instances that a communication source had a significant effect on employees' beliefs, the effect was always in an optimistic direction. For example, respondents who communicated with their supervisors were more likely to believe the robot would decrease accidents. Similarly, recipients of communication about the robot at workplace meetings were more likely to believe the robot would increase productivity. No pattern emerged for the coefficients that did not reach conventional levels of significance.

The communication source most likely to affect employees' beliefs about the robot was the demonstration. Respondents who attended the demonstration were more likely to believe the robot would decrease costs, increase quality, and increase the number of people who work in the department. Thus, the communication source rated by employees as one of the best for increasing their understanding was also the source that had the strongest effect on their beliefs about the robot. The results in Table 2 are generally consistent with those presented in Table 1: while the communication sources did not have much effect on employees' beliefs, the demonstration appears to have been the most effective source of information about the robot.

The effects of the information sources on employees' beliefs about the robot were examined separately for Time 1 and Time 2 (data not shown in table). The results for Time 1 by itself are almost identical to those presented in Table 2 based on data for the combined sample; by Time 2, however, few of the significant relationships remained. Thus, the effects of various communication sources on employees' beliefs appear to be short-lived.

The picture that emerged from our open-ended question about what the company could do to facilitate the introduction of the robot was one of employees wanting to know more about the robot. For example, our respondents suggested:

> "Explain to people how the robot works, what it does."
>
> "Tell employees what's going on and who will be displaced by the robot."
>
> "Get people better informed . . . it seems like a big mystery right now."
>
> "Company should inform people more about the robot and what the company expects to achieve by introducing the robot."

Thus, there was a discrepancy between what employees knew about the robot and what they wanted to know. This qualitative material is consistent with the quantitative material presented in Tables 1 and 2.

Analyses are currently underway to correct any dependence across time in our respondents' perceptions, and to examine the combined effects of the communication sources, time, and demographic variables, such as job tenure, on the dependent measures. Given that the communication sources are correlated with each other, it is extremely doubtful that this latter procedure will reveal any additional significant relationships and hence, the basic finding--that communication sources have little if any effect on employee beliefs--is not likely to change.

Before measures, collected at the second study site, give us data on employees' perceptions of the effectiveness of communication sources. These data are presented in Table 3. The second site used a similar set of communication sources as the first, although a demonstration was not given. A special meeting, however, was held with the group of people whose jobs would be affected by the robot.

The results shown in Table 3 indicate that the workplace meetings were the communication source received by the largest number of employees at this site. Workers rated these meetings as increasing their understanding of the robot between a moderate and a little extent. Communication from their supervisor, which took place in a setting other than the workplace meeting, was rated the most effective by workers. Approximately a quarter of the employees received communication from this source.

The data from our second study site are similar to those from our first study site. In general, workers at both plants did not perceive that the communication sources were very helpful in increasing their understanding of the robots. At a more specific level, however, differences in the data across sites appear. Fewer workers received additional communication from their supervisor at the second study site while more workers learned about the robot through informal sources. Because several employees at the second site were going to be displaced by the robot, supervisors may have been reticent to talk about the change. Employees, on the other hand, were concerned about their jobs and talked about the change among themselves a great deal. Those workers who received additional communication from their supervisor at the second study site rated it more effective than workers at the first site. Written communications were rated less effective at the second site than at the first.

We also examined the extent and type of employee participation in introducing the robot. Workers at our first site were asked how much influence or involvement they actually had on decisions about: (a) whether the robot would be introduced, (b) where it would be placed, and (c) who would run it. We also asked them how much influence they thought they should have had on these decisions. Our respondents reported that they had had no influence on the three decisions and that they thought they should have had some influence on the decisions. They believed they should have had slightly more influence in decisions about whether the robot was introduced and who would run it than on decisions about where the robot was placed, which suggests that employees may want to participate more in some than in other decisions associated with introducing a robot. While the data also suggest that employees at this site did not desire much participation, we might find that employees from different organizational cultures have different preferences about participation, or that workers desire to participate in a different set of decisions than we identified. We are exploring this issue in our current work.

4. Suggestions for Research

Based on our studies of introducing robots, we have developed suggestions for future research on robotics. We are following these suggestions in our own research and believe that they will be useful to other researchers as well. These suggestions fall into five areas: design, sources of data, analyses, levels of analysis, and general methodological issues.

4.1. Design

Our research strategy for studying the implementation of new technologies is to conduct an integrated series of longitudinal studies in different organizations that are introducing different forms of advanced manufacturing technologies. We examine how differences in organizational contexts (e.g., union status, technological sophistication of the plant, employment levels in the community) and in technological characteristics, (e.g., type of technology, similarity to technology already in place, extent of displacement caused by technology) affect employees' reactions to the technology, organizational structures, and outcomes. For example, one might expect that there would be less stress associated with the new technology when it is similar to technologies already in place at the plant. Thus, we feel that a research program on the effects of

robotics should involve studies at multiple organizations.

We also believe that it is important to do in-depth studies at each organization. Since these technologies are being introduced in different types of organizations, it is difficult to compare productivity and other outcomes across the organizations. How does one compare the productivity of company that forges metal products to the productivity of a car manufacturer? Although comparative studies of the relationship between the introduction of new technologies and organizational outcomes such as productivity are very difficult, comparisons over time within each organization are possible. One may compare productivity data obtained before introducing the new technology to data obtained after its introduction. To do this, of course, requires a sufficiently long period of data collection, both before and after the introduction, to rule out seasonal and other shocks as well as the use of a control group, where possible. This approach to assessing the impact of a change on productivity and other outcomes is illustrated in Goodman (1979).

Thus, we feel that a research program on the effects of new technologies requires both in-depth studies and studies at multiple sites. Our research strategy calls for drawing a purposive sample of plants introducing new technologies, a sample that incorporates both union and nonunion plants, etc. While our first study was conducted at a nonunion organization that forges and machines metal products, the second study is underway at a unionized organization with robots on line. The first plant's new technology is a robot that performs material handling activities and the second plant's new installation is a manufacturing cell with two robots. While employees' jobs at the first plant change, no one is displaced by the robot; the second plant's installation, however, displaces some employees and changes the jobs of employees who are retained. Contacts are currently underway for additional sites that incorporate these and other organizational and technological variables. The results of this sampling will be an integrated set of longitudinal studies involving different organizational contexts and different technological characteristics.

4.2. Sources of Data and Respondent Groups

Within each organization our strategy is to collect data using multiple methods and sources to obtain valid and reliable information. Data may be collected through a combination of personal interviews, questionnaires, observation, and records or archival data on productivity, absenteeism, accidents, and turnover. Key respondents include production workers in the department where the new technology is introduced, individuals from other plant departments such as engineering, maintenance, quality control, production scheduling, and personnel relations, and management and supervisory staff.

4.3. Analyses

Statistical analyses of data from the studies focus on changes in key dependent measures that occur after introducing the new technology. Analysis also focus on predicting employees' beliefs and reactions from their proximity to the new technologies, from the communications they received, and from their personal characteristics. In addition, comparisons may be made across study sites. For example, preliminary analyses indicate that the before beliefs of employees at our second study site, where employees are displaced, are more negative than the before beliefs of employees at our first site.

Qualitative material is extremely useful to use along with the quantitative analyses. Indeed, in our first study, some of the more interesting insights came from our respondents' answers to open-ended questions about what they thought a robot was and how it affected them and their jobs. We think it is important to use both open- and closed-ended questions in this stage of our research on the implementation of new

technologies.

4.4. Levels of Analysis

We think research on the effects of new technologies requires multiple levels of analyses. For example, the first research question, the effects of new technologies on employees, requires analysis at the individual level. Since data are collected typically from about 50 individuals at each site at multiple points in time, it is possible to use formal statistical techniques to test hypotheses where the individual is the appropriate level of analysis.

For other questions, such as the effect of the new technology on organizational structures, the department is the appropriate unit of analysis. While the sample size is obviously too small to do formal modeling in this case, the intensive nature of the studies should lead to valuable insights about how and the conditions under which departmental structures change with the introduction of new technologies. These insights could then be tested more formally as data from more sites are accumulated. Methodological issues involved in drawing such comparisons across studies are discussed in Yin (1981).

4.5. Methodological Issues

In a recent paper, Goodman and Argote (in press) discuss general methodological issues one encounters in studying the implementation of new technologies. These issues include: attrition in one's sample over time, the nonindependence of data collected from the same individuals over time, the lack of adequate conceptual schemes for representing technology, lack of instrumentation, problems in sampling the technology users, and the nonequivalence of control groups. Methods for dealing with a couple of these issues (namely sample attrition and nonindependence of data) are summarized below.

An analytic technique for dealing with attrition in samples over time, often a problem in longitudinal organizational research, has been developed and is being used on existing data sets. Employees that a researcher interviews at Time 1, the first wave of data collection, may have left the organization or be absent when the researcher returns to collect subsequent waves of data. This problem is particularly acute in studies of the impacts of advanced manufacturing technologies because the number of employees one interviews at Time 1 is often not large. The sample size, coupled with subsequent samples of employees sampled *without* replacement from the population of employees one interviews at Time 1, creates the need for new methods of assessing the representativeness of subsequent samples.

Although this problem of assessing sample representativeness has been dealt with in other contexts by using a standard χ^2 test, this test is not appropriate for the present problem because the test is based on the multinomial distribution, which assumes that sampling is done with replacement or that the sample space is very large so that the sampling plan does not make a difference. The technique developed in our research is based on the hypergeometric distribution, the appropriate distribution to use when one is sampling from a finite population without replacement. This distribution is used to construct a likelihood ratio test to investigate whether subsequent samples are representative of the "population" of employees interviewed at Time 1. The use of the technique is illustrated in Argote, Goodman, and Schkade (1983).

Another problem one encounters in studying the implementation of new technologies stems from the nonindependence of data collected from the same individuals over time. Because dependent measures of the implementation of new technologies and employee reactions to them are often in the form of a few discrete alternatives (e.g., yes, no), estimation procedures that take account of the discrete nature of the dependent

variable are desirable. However, where the same respondents are interviewed at different time periods, conventional procedures (probit, N-chotomous probit, multinomial logit) are suspect because they fail to account for the temporal correlation in the disturbance terms that can be expected to exist in such a data set. Coefficients estimated by these procedures may be inconsistent and, even where the coefficients are consistent, estimated standard errors generally will not be. Recent developments in econometrics that employ the generalized method of moments (Avery, Hansen & Hotz 1983) provide a methodology for consistently estimating both coefficients and their standard errors in the presence of correlated disturbances of the sort that typically arise in longitudinal data. We are in the process of applying this methodology to the analysis of data presented in Table 2.

5. Suggestions for Practice

What have we learned from our research that may be useful to managers who plan to introduce robots into factories? While findings from our research are just beginning to accumulate, our information coupled with the results from other studies of increased automation suggest some possible strategies for managers to use when introducing robots into their organization. In particular, we have identified five areas of concern for managers: managing job displacement, anticipating how individuals will react to new technologies, anticipating the effects on the organization, implementing change, and being open to change.

5.1. Managing Job Displacement

Prior to introducing robots, employees' concerns need to be anticipated. Questions concerning job security and pay are likely to be uppermost in the minds of the employees, and employees may also be concerned about being bumped to a less desirable job or shift. Failure to deal with these concerns is likely to slow down the speed of the implementation and to reduce the effectiveness of the change.

To deal with employees' concerns about job loss, many companies have successfully used natural attrition to handle any reduction in the number of people needed. While employees may have to change jobs, they still have jobs. If this is not feasible, we believe that it is important for the company to be open with employees and to tell them as soon as possible how many people and who will lose their jobs as a result of the new technology. It is better, for both individuals and the organization to have three people know that they will have to find new jobs rather than to have 30 people worried about job loss. Ideally, these three affected individuals could be given assistance by the company in writing resumes, interviewing, and finding new jobs.

5.2. Anticipating How Individuals Will React

New technologies often change the job activities of individual workers. It is important to analyze the requirements of the new job and maximize the fit or congruency between job and employee characteristics. Research on job-person fit indicates that a lack of congruency may have dysfunctional effects on the person, such as increased stress, and on the organization, including increased absenteeism and turnover. The question is not only whether the employee is able to [illegible]rm the new activities, but whether the employee also likes to perform the new activities. We have [illegible]e, encountered factory workers who prefer manual to cognitive activities; for these employees [illegible] not be a good fit between the job of robot operator and their preferences for manual work. Incong[illegible]s between the job and the person could be dealt with by redesigning the job or by changing personnel selection procedures.

Employees in our first study commented that they had less control after the robot was introduced. We are

currently exploring possible sources for this perception, such as the increased reliance on others, especially engineering and maintenance personnel, that the robot operators experienced and the sense of having their work pace being driven by the robot's cycle time. Since the experience of control has positive consequences for individuals, we believe that it is important to build some control into the robot operator's job. This could be accomplished through increased training or by designing the job so that the robot operator has some control over the cycle time, possibly through having the operator participate in setting the cycle time.

If introducing the robot changes employees' jobs from manual to cognitive activities, employees may experience boredom in the job. Job rotation may be helpful as a mechanism to alleviate boredom. The job rotation would increase variety for the individual worker, build up the skills of other employees and would give the company more flexibility in staffing.

5.3. Anticipating the Effects on the Organization

Introducing new technologies often affects the nature of interaction patterns at work. Previous studies have shown that attempts to change these patterns can generate resistance to change. If one anticipates that the robot will break up existing social relationships that workers value, some alternative mechanisms for interaction should be developed. For example, involving workers in the change may provide them with an opportunity to interact with coworkers as well as increase their understanding of the change. Enabling the worker to communicate with others through alternative modes, such as electronic mail, may buffer the worker from the stress associated with the change and may also lead to greater understanding of the change.

If the robot leads to increased interactions between the production and technical support personnel, new coordination mechanisms may need to be developed. These mechanisms are likely to be especially critical as the number of installations of the new technology increases. As more installations are put on line, technical support personnel will have more demands placed on their time. A procedure for deciding how to assign priorities to the various demands will reduce the pressure on support personnel as well as reduce the potential for conflict among support personnel and the operators of the new technology.

5.4. Implementing Change

A discrepancy often exists between the information employees desire about the new technology and the information they possess, stemming in part from employees not receiving all the messages about the technology that management sends. Hence, we believe it is important for management to monitor whether employees receive communication from particular sources and how helpful employees perceive the sources to be. For example, a management survey might determine how many employees attended the demonstration the company set up about the robot, what employees learned from the demonstration, and what employees want to know about the robot.

Certain information sources seem more effective than others in introducing robotics. Demonstrations of the operation of the new technology seem to be an effective technique. In addition, communications that include both positive and negative messages are more credible and more likely to be believed by employees. To the extent that the new technology has both positive and negative effects (and we believe that this is usually the case), messages mentioning both positive and negative effects will give employees a more realistic preview of what the new technology will entail, which should lead to a smoother implementation. Finally, we have observed companies where employees first learn about the robot by seeing a mysterious crate appear on the factory floor or by hearing from their friends who work in the company's warehouse that a robot has

arrived. Clearly, this is not the most effective way for employees to hear about the robot. Employees who learn about the new technology from management rather than through informal sources are likely to have a more constructive attitude toward the change.

It is vital that first line supervisors be given information about the new technology and that they receive support from upper management in dealing with workers' reactions to it. Studies have shown that communication structures become more centralized, with more reliance on a leader, in periods of threat (Staw, Sandelands & Dutton 1981). This is consistent with our observation that workers go to their supervisor more frequently with questions during the introduction of robots. Supervisors often feel frustrated because they feel they do not have adequate information about the change. Since their attitudes and behaviors will have a big effect on the success of the robot's introduction, it is important that supervisors be given adequate information.

A strategy for worker involvement or participation in introducing new manufacturing technologies should be developed. There are many possible strategies, including the formation of a task force with representatives from departments where robots are being introduced. Management in our two studies provided few opportunities for worker involvement in the robot introductions. Employees wanted more involvement in certain decisions than in others. Involvement may both increase understanding about the new technology and lead to greater commitment to the change process. We think it is important for the company and employees to work out in advance which decisions are going to be made participatively and also what participation means to all involved parties.

Successful implementations of new technologies require the cooperation of technical support personnel. Not all of the support personnel in our first study were involved in planning for the introduction of the robot, and stress was created as a result of this lack of participation. Involving the support personnel early in the change process should facilitate a smooth implementation.

5.5. Being Open to Change

Many of the effects of robots on individuals and organizations can be anticipated. The more a company anticipates these effects, the more likely productivity gains will result from the use of robots. Some of the effects of robots, however, cannot be anticipated. Since these new technologies are just coming into widespread use, there is uncertainty about what their effects will be. We believe it is important for management to create an open culture where both the company and employees can learn about robots and how to use them most effectively. Such a culture is likely to evolve in companies where trust between management and employees already exists, where it is legitimate to say "I don't know" if a person doesn't, and where management and employees are willing to change and update policies and procedures as learning takes place. We believe that the more successful introductions will occur in companies where there is a culture of responsiveness to change.

6. Concluding Comments

Changes in the organization of work, such as job enlargement, autonomous work groups, and quality of work life programs, and technological changes, such as robots and expert systems appear to be moving in different directions. For example, autonomous work groups typically result in workers having more control, learning more skills, performing more significant tasks, and interacting more with members of their work group. While autonomous work groups do not always lead to greater group effectiveness, on balance, the

evidence suggests that members of autonomous work groups are more satisfied, less likely to be absent or to leave the group, and at least as productive as their counterparts in traditional work groups (Katz & Kahn 1978). Hence, many social scientists have advocated the use of changes such as autonomous work groups as a way of increasing the well-being of individual workers and the effectiveness of groups and organizations.

Many technological changes taking place on the factory floor today have an effect on individual workers that is opposite to the effects of social changes such as autonomous work groups. Technological changes such as the introduction of a robot often result in the worker having less control and less opportunity to interact with others while performing a smaller, less significant task. Some of the decisions the workers once made are now embedded in the new technology. Thus, while social changes and technological changes seem to be moving in different directions, this is not too surprising given that the changes are often suggested and designed by people from different professions with different organizational functions.

This divergence between social and technological changes makes it imperative that we, as researchers and as practitioners, get a better handle on the costs and benefits of the two types of changes and the tradeoffs between them. When will it be better for workers to have more control and more influence? When will it be better for decision-making rules to be embedded in the technology rather than in the minds of employees? Under what conditions will interactions with coworkers be beneficial for the individual or the organization? Are current social and technological changes in conflict with one another or can they be used together so that the strengths of one approach complement the weaknesses of the other? Clearly, we need to get a better handle on the costs and benefits of these two different approaches to organizing. Once we have a greater understanding of the tradeoffs between these two different approaches, we can design changes that truly allow for the joint optimization of social and technological systems.

Table 1

Effectiveness of Communication about the Robot: Time One**

Communication Source	% Workers Reporting that They Received Communication	Average Extent Communication Increased Workers' Understanding*
Written communication	16%	2.6
Workplace meetings	89%	4
Communications from supervisor	46%	4.1
Movies or audio-visual presentations	13%	3
Demonstrations	42%	2.7
Informal sources including the grapevine	37%	4

* The response alternatives were: (1) to a very great extent, (2) to a great extent, (3) to a fair extent, (4) to a little extent, (5) not at all.

** Reprinted from the "Human Side of Robotics: How Workers React to a Robot" by Argote, L., Goodman, P. S., & Schkade, D., SLOAN MANAGEMENT REVIEW, Vol. 24, No. 3, pp. 31-41, by permission of the publisher.

Table 2

Probit Analyses:
Effects of Communication Sources on Perceptions of the Effects of a Robot

Effect On:	Written Communication		Workplace Meetings		Supervisor		Demonstration	
	Coefficient	T-Stat	Coefficient	T-Stat	Coefficient	T-Stat	Coefficient	T-Stat
Productivity	-0.60	-0.76	1.37	1.91*	-0.24	-0.43	-0.15	-0.64
Accidents	-0.60	-0.79	-0.11	-0.16	-0.78	-1.75*	0.06	0.73
Costs	0.95	1.03	-0.64	-0.90	-0.20	-0.33	-0.38	-2.07**
Quality	-0.13	-0.63	0.12	0.14	-0.34	-0.75	0.11	1.72*
Number of People	-0.06	-0.48	0.17	0.19	-0.74	-1.68	0.19	1.70*
Boring Jobs	0.16	0.65	0.63	1.33	-0.13	-0.31	0.04	0.64
Chances for a Better Job	-1.18	-1.49	0.20	0.25	0.40	0.85	0.03	0.42

Communication Sources: Written Communication, Workplace Meetings, Supervisor, Demonstration

$^{*}p < .10$

$^{**}p < .05$

Table 3

Perceptions of Workers at the Second Site: Effectiveness of Communication about the Robots at Time One

Communication Source	% Workers Reporting that They Received Communication	Average Extent Communication Increased Workers' Understanding*
Written communication	13%	4.3
Workplace meetings	84%	3.5
Communications from supervisor	26%	2.8
Movies or audio-visual presentations	3%	3.0
Other methods including special meeting	31%	3.1
Informal sources including the grapevine	63%	3.7

* The response alternatives ranged from (1) to a very great extent to (5) not at all.

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8